National Exams December 2009

07-Elec-A5, Electronics

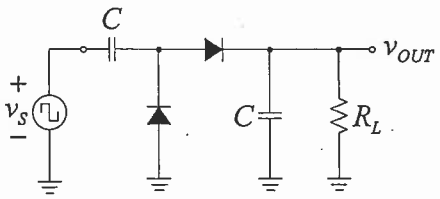
3 hours duration

Notes:

1. If any doubt exists as to the interpretation of any question, the candidate is urged to submit, within their answer, a clear statement of any assumptions made.
2. This is a CLOSED BOOK EXAM.
   One of two calculators is permitted any Casio or Sharp approved models.
3. FIVE (5) questions constitute a complete exam paper.
   The first five questions as they appear in the answer book will be marked.
4. All questions are worth 20 marks each.
5. Please start each question on a new page and clearly identify the question number and part number, e.g. Q4(a).
6. In schematics, ground and chassis may be assumed to be common, unless specifically stated otherwise.
7. Unless otherwise specified, assume that Op-Amps are ideal and that supply voltages are ±15V.
8. Some questions require an answer in essay format. Clarity and organization of the answer are important. Provide block diagrams and circuit schematics whenever necessary.

QUESTION (1)

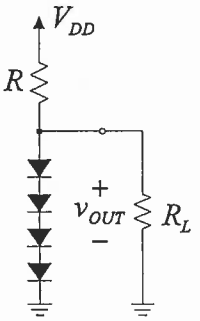
a) The following circuit is supplied by a ±10V square-wave input source with a frequency of 1 kHz. Sketch accurately the output voltage waveform under steady state condition. Including values for various voltage levels and timing information. (10 points)



Given:

All diodes are ideal with 0V forward drop
C = 100 μF
R_L = 100 Ω

b) Consider the circuit on the right. A string of 4 diodes is used to provide a constant voltage of 4 × 0.7 V = 2.8 V. Calculate the percentage change in the output voltage caused by (10 points)



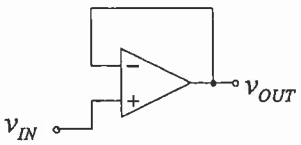
i) a ±10% change in V_{DD} with $R_L = \infty$
ii) a ±10% change in V_{DD} with R_L = 1 kΩ

Given:

All diodes are ideal with 0.7V forward drop, and $n = 2$
$r_d = n \cdot V_T / I_D$
R = 1 kΩ

QUESTION (2)

An op amp with a slew rate of 1 V/μs and a unity-gain bandwidth, f_t of 1 MHz is connected in the unity-gain follower configuration.



a) What is the largest possible input voltage step for which the output voltage waveform can still produce an exponential raise and fall waveform? (8 points)

b) For this input voltage, find the 10% to 90% rise time. (6 points)

c) If the input step is 10 times larger than the voltage that you have found in part (a), find the 10% to 90% rise time. (6 points)

Given:

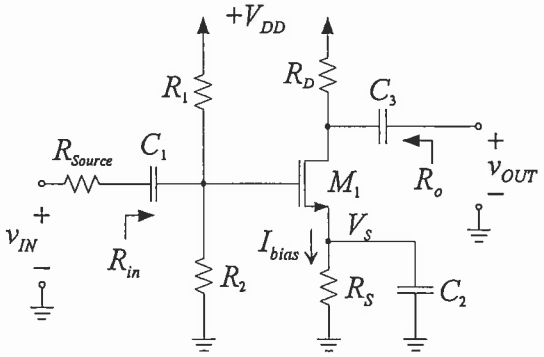
Supply Voltage = ±10 V

Useful Formulae:

$$\frac{V_{OUT}}{V_{IN}} = \frac{1}{1 + s/\omega_t}, \quad v_{OUT}(t) = V\left(1 - e^{-\omega_t t}\right)$$

QUESTION (3)

Consider the common source amplifier circuit on the right. Determine the voltages at all nodes and the current through all branches. (20 points)



Given:

$R_1 = 100\ \text{k}\Omega$	$R_2 = 100\ \text{k}\Omega$
$R_D = 6\ \text{k}\Omega$	$R_S = 6\ \text{k}\Omega$
$V_{TH} = 1\text{V}$	$\lambda = 0\ \text{V}^{-1}$

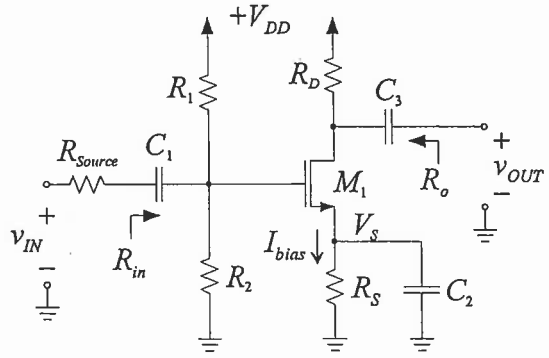
Useful formulae: for n-channel MOSFET

$$i_{DS} = \mu_n C_{ox} \frac{W}{L}\left[(v_{GS} - V_{TH})v_{DS} - \frac{1}{2}v_{DS}^2\right] \quad \text{triode region}$$

$$i_{DS} = \frac{1}{2}\mu_n C_{ox} \frac{W}{L}(v_{GS} - V_{TH})^2(1 + \lambda v_{DS}) \quad \text{saturation region}$$

QUESTION (4)

Consider the common source amplifier circuit on the right. Determine the mid-band gain A_M and the upper 3dB frequency f_H. (20 points)



Given:

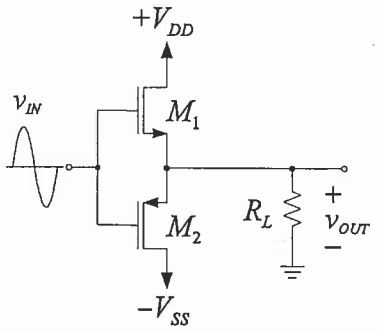
$R_1//R_2 = 4.7\ \text{M}\Omega$		$R_{source} = 100\ \text{k}\Omega$	
R_D	$= 15\ \text{k}\Omega$	R_L	$= 15\ \text{k}\Omega$
g_m	$= 1\ \text{mA/V}$	r_o	$= 150\ \text{k}\Omega$
C_{gs}	$= 1\ \text{pF}$	C_{gd}	$= 0.4\ \text{pF}$
C_1	$= \infty$	C_2	$= \infty$
C_3	$= \infty$		

QUESTION (5)

The NMOS and PMOS transistor in this circuit are matched. Determine:

a) the drain currents through both transistors at $v_{IN} = 0$ V (10 points)

b) the gain of this circuit at $V_{IN} = 0$ V (10 points)



Given:

$k_n'(W_n/L_n) = k_p'(W_p/L_p) = 1\ \text{mA/V}^2$

$V_{tn} = V_{tp} = 1$ V

$\lambda = 0$

QUESTION (6)

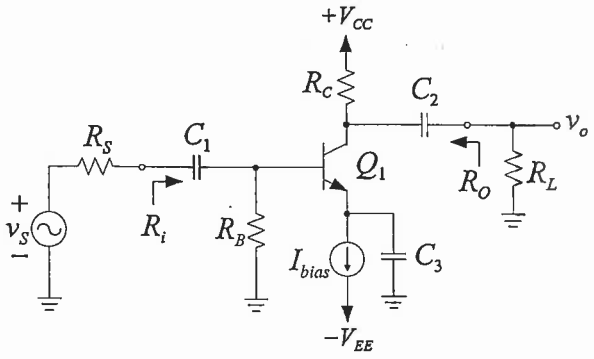
For the following common emitter amplifier, find:

a) the mid-band gain (10 points)

b) the upper 3dB cutoff frequency (10 points)

Given:

V_{CC}	= +10 V	$-V_{EE}$	= −10V
I_{bias}	= 1 mA	R_B	= 100 kΩ
R_C	= 8 kΩ	R_S	= 5 kΩ
β_0	= 100	V_A	= 100 V
C_μ	= 1 pF	f_T	= 800 MHz
r_x	= 50Ω		



Hint: hybrid-π model: